

(19)



(11)

EP 3 917 037 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
01.12.2021 Bulletin 2021/48

(51) Int Cl.:
H04B 10/67 (2013.01) **H03F 3/08** (2006.01)
H03G 3/30 (2006.01) **H04B 10/69** (2013.01)

(21) Application number: **21175375.1**

(22) Date of filing: **21.05.2021**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

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(30) Priority: **27.05.2020 CN 202010460144**

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(54) **OPTICAL RECEIVING DEVICE**

(57) An optical receiving device includes a conversion module, a signal generation module and a control module. The conversion module performs photoelectric conversion and amplification on an optical signal to generate a photocurrent, the signal generation module provides a gain signal, performs transimpedance and amplification on the photocurrent according to an input signal indicating a preset output voltage swing to generate

a voltage signal, and generates a measurement signal indicating an average optical power associated with the optical signal according to the photocurrent, the control module outputs a control signal which is variable to adjust a gain of the conversion module, so that a dynamic range of the conversion module changes as the gain of the conversion module itself changes.

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Description**TECHNICAL FIELD**

[0001] The present disclosure relates to a device, and particularly relates to an optical receiving device.

BACKGROUND

[0002] An existing optical communication system includes an optical transmitting device, an optical fiber, an optical receiving device, an adjustable optical attenuator, an optical splitter and an optical detector.

[0003] The optical transmitting device is used to transmit an optical signal of a multilevel pulse amplitude modulation, and transfer the optical signal to the optical splitter sequentially via the optical fiber and the adjustable optical attenuator. The optical splitter splits the received optical signal into a first optical signal and a second optical signal, and transfers the first optical signal and the second optical signal to the optical detector and the optical receiving device respectively. The optical receiving device performs photoelectric conversion, amplification and demodulation on the received second optical signal to generate a digital data output, so as to allow a post-stage digital circuit to use. The optical detector generates a measurement signal indicating an optical power of the optical signal according to the first optical signal, and transfers the measurement signal to the adjustable optical attenuator. According to the measurement signal, the adjustable optical attenuator decides whether the optical signal received via the optical fiber optical is first performed for power attenuation and adjustment and then outputted to the optical splitter so that the optical receiving device will not cause a semiconductor optical amplifier inside to be operated at a saturation region because an optical power of the second optical signal received by the optical receiving device from the optical splitter is too large, so as to avoid the digital data output generated by the optical receiving device being inaccurate because the semiconductor optical amplifier is operated at the saturation region.

[0004] As such, in addition to the basic elements, such as the optical transmitting device, the optical fiber and the optical receiving device, included by the existing optical communication system, it additionally requires the existing optical communication system to further include the adjustable optical attenuator, the optical splitter and the optical detector, which results in that the existing optical communication system has a larger volume and a higher cost. Moreover, a dynamic range of the optical receiving device associated with an inputting power of the optical signal is more limited. Therefore, the existing optical communication system still has an improved space.

SUMMARY

[0005] Therefore, an object of the present disclosure is to provide an optical receiving device which can overcome a deficiency of the existing technology.

[0006] Accordingly, an optical receiving device of the present disclosure comprises a conversion module, a signal generation module and a control module. The conversion module is used to receive an optical signal from an optical fiber and perform photoelectric conversion and amplification on the optical signal to generate a photocurrent. The signal generation module receives an input signal indicating a preset output voltage swing, and electrically connects the conversion module to receive the photocurrent, the signal generation module provides a gain signal indicating a total gain itself, and performs transimpedance and amplification on the photocurrent according to the input signal to generate a voltage signal, and generates a measurement signal indicating an average optical power associated with the optical signal according to the photocurrent. The control module electrically connects the conversion module and the signal generation module, and outputs a control signal which is variable to the conversion module to adjust a gain of the conversion module, so that a dynamic range of the conversion module changes as the gain of the conversion module itself changes.

[0007] The technical effect of the present disclosure lies in that: by that the control module generates the control signal to adjust the gain of the conversion module, the dynamic range of the conversion module may be further increased therewith, so that the transfer distance of the optical signal via the optical fiber is less limited, in turn link performance is promoted.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Other features and technical effects of the present disclosure will be apparent in an embodiment referring to the accompanying figures, in which:

FIG. 1 is a block diagram illustrating a first embodiment of an optical receiving device of the present disclosure is used for an optical communication system;

FIG. 2 is a simulation diagram illustrating a gain of a semiconductor optical amplifier of the first embodiment itself changes with an inputting power under different driving currents;

FIG. 3 is a simulation diagram illustrating a bit error rate changes with the inputting powers when the gain of the semiconductor optical amplifier of the first embodiment is constant;

FIG. 4 is a simulation diagram illustrating an extinction ratio changes with the inputting powers when the gain of the semiconductor optical amplifier of the first embodiment is constant;

FIG. 5 is a simulation diagram illustrating the bit error

rate changes with the inputting power when the gain of the semiconductor optical amplifier of the first embodiment is not constant;
 FIG. 6 is a simulation diagram illustrating the extinction ratio changes with the inputting power when the gain of the first embodiment of the semiconductor optical amplifier is not constant;
 FIG. 7 is a block diagram illustrating a second embodiment of the optical receiving device of the present disclosure; and
 FIG. 8 is a block diagram illustrating a third embodiment of the optical receiving device of the present disclosure is used for another optical communication system.

[0009] The reference numerals are represented as follows:

1 optical receiving device
 10 optical communication system
 11, 11a, 11b conversion module
 111, 116 semiconductor optical amplifier
 112 optical band-pass filter
 113, 118 photodetector
 114 photoelectric convertor
 115 biasing voltage generator
 117 demultiplexer
 12, 12a signal generation module
 121 power detector
 122 transimpedance amplifier
 123 variable gain amplifier
 124 automatic gain controller
 125 signal generation unit
 13 control module
 14 multilevel pulse amplitude demodulator
 15 estimation module
 2 optical transmitting device
 3 optical fiber
 Ac gain control signal
 Cs control signal
 Do data output
 Do 1-Don data output
 DR, DR' dynamic range
 Es estimating signal
 Gs gain signal
 Gs1-Gsn gain signal part
 La amplified optical signal
 Lf filtered optical signal
 L1-Ln adjusting optical signal
 Ls optical signal
 Ms measurement signal
 Ms1-Msn measurement signal part
 Pb preset bit error rate threshold
 Pc photocurrent
 Pc1-Pcn photocurrent part
 Pt preset extinction ratio threshold
 Q position
 Q1 first inputting power

Q2 second inputting power
 Si input signal
 Si1-Sin input signal part
 Va amplified voltage signal
 Vb biasing voltage
 Vs voltage signal
 Vs1-Vsn voltage signal part

DETAILED DESCRIPTION

[0010] Before the present disclosure is described in detail, it should be noted that like elements are denoted by the same reference numerals in the following description.

<First Embodiment>

[0011] Referring to FIG. 1, an embodiment of an optical receiving device 1 of the present disclosure is adapted to an optical communication system 10. The optical communication system 10 includes an optical transmitting device 2 and an optical fiber 3. The optical transmitting device 2 is used to transmit an optical signal Ls of a multilevel pulse amplitude modulation (PAM-N) and transfer the optical signal Ls to the optical receiving device 1 via the optical fiber 3. The optical signal Ls is an at least four level multilevel pulse amplitude modulation signal. In the present embodiment, that the optical signal Ls is a four level pulse amplitude modulation signal is taken as an example, but the present disclosure is not limited thereto.

[0012] The optical receiving device 1 of the present embodiment includes a conversion module 11, a signal generation module 12, a control module 13 and a multilevel pulse amplitude demodulator 14.

[0013] The conversion module 11 is used to receive the optical signal Ls from the optical fiber 3, and perform photoelectric conversion and amplification on the optical signal Ls to generate a photocurrent Pc. In the present embodiment, the conversion module 11 includes a semiconductor optical amplifier 111, an optical band-pass filter 112 and a photodetector/optical detector 113.

[0014] The semiconductor optical amplifier 111 is used to receive the optical signal Ls and receive a control signal Cs which is variable. The semiconductor optical amplifier 111 adjusts a gain itself according to the control signal Cs and amplifies the optical signal Ls to generate an amplified optical signal La. The gain of the semiconductor optical amplifier 111 is acted as a gain of the conversion module 11. Specifically, a driving current of the semiconductor optical amplifier 111 changes as the control signal Cs changes, and the gain of the semiconductor optical amplifier 111 changes as the driving current changes. Further referring to FIG. 2, FIG. 2 illustrates a relationship between the gain of the semiconductor optical amplifier 111 and an inputting power of the optical signal Ls under different driving currents. As can be seen from FIG. 2, if a larger (smaller) gain of the semiconductor optical amplifier 111 is desired, the driving current will be

increased (decreased) according to the control signal Cs.

[0015] The optical band-pass filter 112 couples the semiconductor optical amplifier 111 to receive the amplified optical signal La and band-pass filter the amplified optical signal La to generate a filtered optical signal Lf. Specifically, the optical band-pass filter 112 is used to allow an optical signal having a wavelength to be detected to pass through, and filter out other optical signal having a wavelength not to be detected.

[0016] The photodetector 113 couples the optical band-pass filter 112 to receive the filtered optical signal Lf and photoelectrically convert the filtered optical signal Lf to the photocurrent Pc.

[0017] The signal generation module 12 receives an input signal Si indicating a preset output voltage swing, and electrically connects the photodetector 113 of the conversion module 11 to receive the photocurrent Pc. The signal generation module 12 provides a gain signal Gs indicating a total gain itself. The signal generation module 12 performs transimpedance and amplification on the photocurrent Pc according to the input signal Si to generate a voltage signal Vs, and generates a measurement signal Ms indicating an average optical power associated with the optical signal Ls according to the photocurrent Pc. The measurement signal Ms is acted as a received signal strength indication (RSSI) of the optical receiving device 1. The voltage signal Vs is an at least four level multilevel pulse amplitude modulation signal. In the present embodiment, the voltage signal Vs is a four level pulse amplitude modulation signal, but the present disclosure is not limited thereto. The signal generation module 12 includes a power detector 121, a transimpedance amplifier 122, a variable gain amplifier 123 and an automatic gain controller 124.

[0018] The power detector 121 electrically connects the photodetector 113 to detect the photocurrent Pc and generate the measurement signal Ms according to the photocurrent Pc.

[0019] The transimpedance amplifier 122 electrically connects the photodetector 113 to receive the photocurrent Pc and perform transimpedance and amplification on the photocurrent Pc to generate an amplified voltage signal Va.

[0020] The variable gain amplifier 123 receives a gain control signal Ac indicating a variable gain, and electrically connects the transimpedance amplifier 122 to receive the amplified voltage signal Va. The variable gain amplifier 123 adjusts a gain itself to the variable gain according to the gain control signal Ac and amplifies the amplified voltage signal Va to generate the voltage signal Vs.

[0021] The automatic gain controller 124 receives the input signal Si, and electrically connects the variable gain amplifier 123 to receive the voltage signal Vs. The automatic gain controller 124 provides the gain signal Gs, and the total gain indicated by the gain signal Gs is a sum of gains of the transimpedance amplifier 122 and the variable gain amplifier 123 (so the automatic gain

controller 124 prestores a gain of the transimpedance amplifier 122, and the gain of the transimpedance amplifier 122 is constant). The automatic gain controller 124 performs a comparison between a voltage swing of the voltage signal Vs and the preset output voltage swing indicated by the input signal Si to adjust and generate the gain control signal Ac according to a result from the comparison and output the gain control signal Ac to the variable gain amplifier 123. For example, when the voltage swing of the voltage signal Vs is less than the preset output voltage swing, the automatic gain controller 124 promotes the variable gain of the gain control signal Ac, in turn the gain of the variable gain amplifier 123 increases with the gain control signal Ac under control of the gain control signal Ac, so that the voltage swing of the voltage signal Vs is gradually adjusted to be equal to the preset output voltage swing, so as to ensure an output magnitude of the voltage signal Vs to be conformed with the requirement of a post-stage circuit.

[0022] The control module 13 electrically connects the semiconductor optical amplifier 111 of the conversion module 11 and the power detector 121 and the automatic gain controller 124 of the signal generation module 12. The control module 13 is used to receive the input signal Si and output the input signal Si to the automatic gain controller 124, and further receive respectively the gain signal Gs from the automatic gain controller 124 and the measurement signal Ms from the power detector 121. The control module 13 generates the control signal Cs at least according to the input signal Si, the gain signal Gs and the measurement signal Ms and outputs the control signal Cs to the semiconductor optical amplifier 111 to adjust the gain of the semiconductor optical amplifier 111 of the conversion module 11, so that a dynamic range of the conversion module 11 changes as the gain of the semiconductor optical amplifier 111 changes.

[0023] Specifically, the control module 13 obtains an extinction ratio according to the input signal Si, the gain signal Gs, the measurement signal Ms, and an optical responsivity associated with the photoelectric conversion of the photodetector 113, the extinction ratio is used to judge whether the semiconductor optical amplifier 111 of the conversion module 11 is operated at a saturation region, and the control module 13 performs a comparison between the extinction ratio and a preset extinction ratio threshold to adjust and generate the control signal Cs according to a results from the comparison, so that when the extinction ratio is less than the preset extinction ratio threshold (that is, it represents that the semiconductor optical amplifier 111 is operated at the saturation region rather than a linear region, which will result in deformation of an eye diagram of the amplified optical signal La, in turn affect accuracy of demodulation of the post-stage circuit), the gain of the semiconductor optical amplifier 111 is lowered under control of the control signal Cs, which makes the extinction ratio after adjusted is greater than or is equal to the preset extinction ratio threshold, so as to make the semiconductor optical amplifier 111

be operated at the linear region. The extinction ratio may be obtained from the following equation (1);

$$ER = \frac{2 \times P_{avg} + O_{ma}}{2 \times P_{avg} - O_{ma}} \quad \text{equation (1),}$$

where, a parameter ER is the extinction ratio, a parameter P_{avg} is associated with a ratio of the measurement signal M_s and the optical responsivity, a parameter O_{ma} is associated with a ratio of the input signal S_i and the gain signal G_s .

[0024] The multilevel pulse amplitude demodulator 14 electrically connects the variable gain amplifier 123 to receive the voltage signal V_s and demodulate the voltage signal V_s to generate a data output D_o .

[0025] Referring to FIG. 3 and FIG. 4, FIG. 3 illustrates a relationship between a bit error rate (BER) of the data output D_o and an inputting power of the optical signal L_s (which depends on a loss of the optical fiber 3) when the gain of the semiconductor optical amplifier 111 is constant. FIG. 4 illustrates a relationship between the extinction ratio ER and the inputting power of the optical signal L_s when the gain of the semiconductor optical amplifier 111 is constant. In FIG. 3, when the bit error rate is less than or equal to a preset bit error rate threshold P_b , the optical communication system 10 has a better link performance, and it is preferable to maximize a dynamic range of the optical receiving device 1 (that is, the dynamic range of the conversion module 11 represented by a symbol DR in FIG. 3) at various optical fiber transmission lengths. Because, as for a smaller inputting power of the optical signal L_s (that is, before a Q point), the bit error rate of the data output D_o is limited by a noise of the optical communication system 10, but as for a larger inputting power of the optical signal L_s (that is, after the Q point), the link performance of the optical communication system 10 will become poor, and the bit error rate of the data output D_o is limited by nonlinear distortion caused by the semiconductor optical amplifier 111 (that is, the semiconductor optical amplifier 111 is operated at the saturation region). Therefore, it may attain an inputting power range of the optical signal L_s of the best link performance by adjusting a starting position (that is, Q point) of the nonlinear distortion where the semiconductor optical amplifier 111 is operated, so as to maximize the dynamic range DR of the optical receiving device 1. Also, as shown in FIG. 4, as for linear operation of the amplified optical signal L_a , because the gain of the semiconductor optical amplifier 111 corresponding to a smaller inputting power of the optical signal L_s (that is, before the Q point) linearly changes, the extinction ratio ER is maintained constant. However, as for a larger inputting power of the optical signal L_s (that is, after the Q point), because the gain of the semiconductor optical amplifier 111 gradually becomes nonlinear (that is, the semiconductor optical amplifier 111 is operated at the saturation region), the extinction ratio ER begins to be less than the

preset extinction ratio threshold. Therefore, the optical receiving device 1 of the present disclosure determines whether the semiconductor optical amplifier 111 is operated at the linear region by judging whether the extinction ratio ER is less than the preset extinction ratio threshold (that is, represented by a symbol P_t in FIG. 4), and when the extinction ratio ER is less than the preset extinction ratio threshold P_t , the optical receiving device 1 lowers the gain of the semiconductor optical amplifier 111 (that is, decreases the driving current of the semiconductor optical amplifier 111), to make the starting position Q of the nonlinear distortion where the semiconductor optical amplifier 111 is operated be postponed therewith, so that the dynamic range of the conversion module 11 increases therewith, a transfer distance of the optical signal L_s via the optical fiber 3 is less limited so as to promote link transmission performance.

[0026] Referring to FIG. 5 and FIG. 6, FIG. 5 and FIG. 6 respectively differ from FIG. 3 and FIG. 4 in that, the gain of the semiconductor optical amplifier 111 is not constant. It can be seen from simulation diagrams of FIG. 5 and FIG. 6, when an inputting power of the optical signal L_s is greater than a first inputting power Q_1 , the extinction ratio ER begins to be less than the preset extinction ratio threshold P_t . Therefore, the control module 13 lowers the gain of the semiconductor optical amplifier 111, to make the semiconductor optical amplifier 111 continuously be operated at the linear region, and the semiconductor optical amplifier 111 from operated at the linear region turns to that the starting position of the saturation region is postponed therewith from a position where the first inputting power Q_1 is located to a position where a second inputting power Q_2 is located, in turn a dynamic range DR' of the conversion module 11 increases therewith, so the optical receiving device 1 of the present disclosure indeed has a preferable link performance.

[0027] It is noted that, in other embodiments, the optical receiving device 1 further includes an estimation module (not shown) which is electrically connected between the multilevel pulse amplitude demodulator 14 and the control module 13. The estimation module generates an estimating signal (which is associated with one of a bit error rate and a signal-to-noise ratio (SNR) of the optical signal L_s) according to the data output D_o and outputs the estimating signal to the control module 13, so that the control module 13 adjusts the control signal C_s further according to the estimating signal.

<Second Embodiment>

[0028] Referring to FIG. 7, a second embodiment of the optical receiving device 1 of the present disclosure is similar to the first embodiment, but differs from the first embodiment in that, in the second embodiment: (1) a conversion module 11a replaces the conversion module 11 of the first embodiment (see FIG. 1), the conversion module 11a includes a photoelectric convertor 114 and a biasing voltage generator 115; and (2) the power de-

tor 121 electrically connects the photoelectric converter 114 rather than the photodetector 113 (see FIG. 1).

[0029] The photoelectric converter 114 receives a biasing voltage V_b , and is used to receive the optical signal L_s from the optical fiber 3. The photoelectric converter 114 adjusts a gain itself according to the biasing voltage V_b (for example, when the biasing voltage V_b increases, the gain of the photoelectric converter 114 increases therewith), and performs photoelectric conversion and amplification on the optical signal L_s to generate the photocurrent P_c . In the present embodiment, the gain of the photoelectric converter 114 is acted as a gain of the conversion module 11a. The photoelectric converter 114 is made of an avalanche photon diode.

[0030] The biasing voltage generator 115 is electrically connected between the photoelectric converter 114 and the control module 13, receives the control signal C_s from the control module 13, and adjusts and generates the biasing voltage V_b according to the control signal C_s , and outputs the biasing voltage V_b to the photoelectric converter 114.

[0031] It is noted that, the control module 13 obtains the extinction ratio ER at least according to the input signal S_i , the gain signal G_s , the measurement signal M_s , and an optical responsivity associated with photoelectric conversion of the photoelectric converter 114, and in the equation (1), the parameter P_{avg} is associated with the measurement signal M_s , the optical responsivity and the gain of the photoelectric converter 114. An operation of the second embodiment of the optical receiving device 1 is similar to the operation of the first embodiment of the optical receiving device 1, so the description thereof is omitted.

<Third Embodiment>

[0032] Referring to FIG. 8, a third embodiment of the optical receiving device 1 of the present disclosure is used for another optical communication system, and the another optical communication system is a wavelength division multiplexing (WDM) transfer system. The third embodiment is similar to the first embodiment, the third embodiment differs from the first embodiment in that, in the third embodiment: (1) the optical signal L_s has a plurality of multilevel pulse amplitude modulation signals which each are an at least four level pulse amplitude modulation signal (in the present embodiment, that each multilevel pulse amplitude modulation signal is a four level pulse amplitude modulation signal is taken as an example, but the present disclosure is not limited thereto); (2) a plurality of photocurrent parts P_{c1} - P_{cn} constitute the photocurrent P_c (see FIG. 1), a plurality of gain signal parts G_{s1} - G_{sn} constitute the gain signal G_s (see FIG. 1), a plurality of measurement signal parts M_{s1} - M_{sn} constitute the measurement signal M_s , a plurality of voltage signal parts V_{s1} - V_{sn} constitute the voltage signal V_s ; (3) a plurality of input signal parts S_{i1} - S_{in} constitute the input signal S_i (see FIG. 1), the plurality of input signal parts

S_{i1} - S_{in} respectively indicate a plurality of preset output voltage swing parts, the plurality of preset output voltage swing parts constitute the preset output voltage swing indicated by the input signal S_i ; (4) a conversion module 11b and a signal generation module 12a respectively replace the conversion module 11 and the signal generation module 12 of the first embodiment (see FIG. 1); and (5) a plurality of multilevel pulse amplitude demodulators 14 and an estimation module 15 are further included.

[0033] In the present embodiment, the conversion module 11b includes a semiconductor optical amplifier 116, a demultiplexer 117 and a plurality of photodetectors 118. It is noted that, because an operation of the semiconductor optical amplifier 116 is similar to the operation of the semiconductor optical amplifier 111 of FIG. 1, the description thereof is omitted.

[0034] The demultiplexer 117 couples the semiconductor optical amplifier 116 to receive the amplified optical signal L_a and demultiplex the amplified optical signal L_a to generate a plurality of adjusting optical signals L_{1-1n} which are respectively associated with the plurality of multilevel pulse amplitude modulation signals of the optical signal L_s .

[0035] The plurality of photodetectors 118 couple the demultiplexer 117 to respectively receive the plurality of adjusting optical signals L_{1-1n} and respectively photoelectrically convert the plurality of adjusting optical signals L_{1-1n} to the plurality of photocurrent part P_{c1} - P_{cn} correspondingly.

[0036] In the present embodiment, the signal generation module 12a includes a plurality of signal generation units 125. It is noted that, because the detailed components and the operation of each signal generation unit 125 are similar to those of the signal generation module 12 of FIG. 1, only signal generation unit 125 in the top most is taken as an example and simply described.

[0037] The signal generation unit 125 electrically connects the control module 13 to receive the corresponding input signal part S_{i1} , and electrically connects the corresponding photodetector 118 to receive the corresponding photocurrent part P_{c1} . The signal generation unit 125 provides the corresponding gain signal part G_{s1} , and amplifies the corresponding photocurrent part P_{c1} according to the corresponding input signal part S_{i1} to generate the corresponding voltage signal part V_{s1} , and generates the corresponding measurement signal part M_{s1} indicating an average optical power of the corresponding photocurrent part P_{c1} according to the corresponding photocurrent part P_{c1} .

[0038] The plurality of multilevel pulse amplitude demodulators 14 respectively electrically connect the plurality of signal generation units 125 to respectively receive the plurality of voltage signal parts V_{s1} - V_{sn} , and demodulate the plurality of voltage signal parts V_{s1} - V_{sn} respectively to respectively generate a plurality of data outputs D_{o1} - D_{on} .

[0039] The estimation module 15 electrically connects the control module 13, and electrically connects the plu-

rality of multilevel pulse amplitude demodulators 14 to receive the plurality of data outputs Do 1-Don, and generates an estimating signal Es according to the plurality of data outputs Do 1-Don and outputs the estimating signal Es to the control module 13, so that the control module 13 adjusts the control signal Cs further according to the estimating signal Es. In the present embodiment, the estimating signal Es is associated with one of the bit error rate and the signal-to-noise ratio of the optical signal Ls.

[0040] It is noted that, an operation of the third embodiment of the optical receiving device 1 and is similar to the operation of the first embodiment of the optical receiving device 1, the description thereof is omitted. Moreover, manners that the control module 13 adjusts the control signal Cs are: (1) obtaining a plurality of extinction ratios at least according to the plurality of input signal parts Si1-Sin, the plurality of gain signal parts Gs1-Gsn and the plurality of measurement signal parts Ms1-Msn to adjust the control signal Cs; (2) obtaining the extinction ratio only according to the input signal part, the gain signal part and the measurement signal part correspondingly outputted by one of signal generation units 125 and a corresponding optical responsivity to adjust the control signal Cs; (3) adjusting the control signal Cs only according to the estimating signal Es; and (4) comprehensively considering the extinction ratio from the manner (2) and the estimating signal Es from the manner (3) to adjust the control signal Cs, but the present disclosure is not limited thereto.

[0041] In conclusion, by cooperation between the signal generation module 12 (12a) and the control module 13 inside the optical receiving device 1 itself, the optical receiving device 1 of the present disclosure knows whether the semiconductor optical amplifier 111 (116) or the photoelectric convertor 114 is operated at the saturation region, and the control module 13 will perform corresponding gain control on the semiconductor optical amplifier 111 (116) or the photoelectric convertor 114 to avoid the problem that the semiconductor optical amplifier 111(116) or the photoelectric convertor 114 is operated at the saturation region. As such, the optical communication system which employs the optical receiving device 1 of the present disclosure may omit the adjustable optical attenuator, the optical splitter and the optical detector which are additionally provided in the existing optical communication system. Therefore, the optical communication system which employs the optical receiving device 1 of the present disclosure has a smaller volume and a lower cost in comparison with the existing optical communication system. Moreover, by adjusting the gain of the semiconductor optical amplifier 111 (116) or the photoelectric convertor 114, the dynamic range of the conversion module 11 (11a, 11b) may be further increased therewith, so that the transfer distance of the optical signal Ls via the optical fiber 3 is less limited, in turn link performance is promoted.

[0042] However, the above description is only for the embodiments of the present disclosure, and it is not in-

tended to limit the implementing scope of the present disclosure, and the simple equivalent changes and modifications made according to the claims and the contents of the specification are still included in the scope of the present disclosure.

Claims

1. An optical receiving device, comprising:

a conversion module which is used to receive an optical signal from an optical fiber and perform photoelectric conversion and amplification on the optical signal to generate a photocurrent; a signal generation module which receives an input signal indicating a preset output voltage swing, and electrically connects the conversion module to receive the photocurrent, the signal generation module providing a gain signal indicating a total gain itself, and performing transimpedance and amplification on the photocurrent according to the input signal to generate a voltage signal, and generating a measurement signal indicating an average optical power associated with the optical signal according to the photocurrent; and

a control module which electrically connects the conversion module and the signal generation module, and outputs a control signal which is variable to the conversion module to adjust a gain of the conversion module, so that a dynamic range of the conversion module changing as the gain of the conversion module itself changing.

2. The optical receiving device of claim 1, wherein the conversion module comprises:

a semiconductor optical amplifier which is used to receive the optical signal from the optical fiber, and electrically connects the control module to receive the control signal, the semiconductor optical amplifier adjusts a gain itself according to the control signal and amplifies the optical signal to generate an amplified optical signal, the gain of the semiconductor optical amplifier is acted as the gain of the conversion module, an optical band-pass filter which couples the semiconductor optical amplifier to receive the amplified optical signal, and band-pass filters the amplified optical signal to generate a filtered optical signal, and a photodetector which couples the optical band-pass filter to receive the filtered optical signal and photoelectrically convert the filtered optical signal into the photocurrent.

3. The optical receiving device of claim 1, wherein the

conversion module comprises:

a photoelectric convertor which receives a biasing voltage, and is used to receive the optical signal from the optical fiber, the photoelectric convertor adjusts a gain itself according to the biasing voltage and performs photoelectric conversion and amplification on the optical signal to generate the photocurrent, the gain of the photoelectric convertor is acted as the gain of the conversion module, and
 a biasing voltage generator which is electrically connected between the photoelectric convertor and the control module, receives the control signal from the control module, and adjusts and generates the biasing voltage according to the control signal, and outputs the biasing voltage to the photoelectric convertor.

- 4. The optical receiving device of claim 3, wherein the photoelectric convertor is made of an avalanche photon diode.
- 5. The optical receiving device of claim 1, wherein the optical signal and the voltage signal each are an at least four level multilevel pulse amplitude modulation signal.
- 6. The optical receiving device of claim 1, wherein the signal generation module comprises:

a power detector which electrically connects the conversion module to detect the photocurrent, generate the measurement signal according to the photocurrent and output the measurement signal to the control module,
 a transimpedance amplifier which electrically connects the conversion module to receive the photocurrent and perform transimpedance and amplification on the photocurrent to generate an amplified voltage signal,
 a variable gain amplifier which receive a gain control signal indicating a variable gain, and electrically connects the transimpedance amplifier to receive the amplified voltage signal, the variable gain amplifier adjusts a gain itself to the variable gain according to the gain control signal and amplifies the amplified voltage signal to generate the voltage signal, and
 an automatic gain controller which electrically connects the variable gain amplifier and the control module to respectively receive the voltage signal and the input signal, and perform a comparison between a voltage swing of the voltage signal and the preset output voltage swing indicated by the input signal to adjust and generate the gain control signal according to a result from the comparison and output the gain control sig-

nal to the variable gain amplifier,
 the automatic gain controller further provides the gain signal, a total gain indicated by the gain signal is a sum of gains of the transimpedance amplifier and the variable gain amplifier.

- 7. The optical receiving device of claim 1, further comprising:
 a multilevel pulse amplitude demodulator which electrically connects the signal generation module to receive the voltage signal and demodulate the voltage signal to generate a data output.
- 8. The optical receiving device of claim 1, wherein the control module is used to receive the input signal and output the input signal to the signal generation module, and further receive the gain signal and the measurement signal from the signal generation module, the control module obtains an extinction ratio according to the input signal, the gain signal, the measurement signal and an optical responsivity associated with photoelectric conversion of the conversion module, the extinction ratio is used to judge whether the conversion module is operated at a saturation region, and perform a comparison between the extinction ratio and a preset extinction ratio threshold to adjust and generate the control signal according to a result from the comparison, so that when the extinction ratio is less than the preset extinction ratio threshold, the gain of the conversion module is lowered under control of the control signal.
- 9. The optical receiving device of claim 1, wherein the optical signal has a plurality of multilevel pulse amplitude modulation signals which each are an at least four level pulse amplitude modulation signal, the photocurrent has a plurality of photocurrent parts, the conversion module comprises:

a semiconductor optical amplifier which is used to receive the optical signal from the optical fiber, and electrically connects the control module to receive the control signal, the semiconductor optical amplifier adjusts a gain itself according to the control signal and amplifies the optical signal to generate an amplified optical signal, the gain of the semiconductor optical amplifier is acted as the gain of the conversion module,
 a demultiplexer which couples the semiconductor optical amplifier to receive the amplified optical signal and demultiplex the amplified optical signal to generate a plurality of adjusting optical signals respectively associated with the plurality of multilevel pulse amplitude modulation signals, and
 a plurality of photodetectors which couple the demultiplexer to respectively receive the plurality of adjusting optical signals and respectively

photoelectrically convert the plurality of adjusting optical signals to the plurality of photocurrent parts correspondingly.

10. The optical receiving device of claim 9, wherein the preset output voltage swing has a plurality of preset output voltage swing parts, the input signal has a plurality of input signal parts which each indicate the corresponding one of the plurality of preset output voltage swing parts, the gain signal has a plurality of gain signal parts, the voltage signal has a plurality of voltage signal parts, the signal generation module comprises:

a plurality of signal generation units, each signal generation unit electrically connects the control module to receive the corresponding input signal part, and electrically connects the corresponding photodetector to receive the corresponding photocurrent part, each signal generation unit provides the corresponding gain signal part and amplifies the corresponding photocurrent part according to the corresponding input signal part to generate the corresponding voltage signal part, and generates a measurement signal part indicating an average optical power of the corresponding photocurrent part according to the corresponding photocurrent part, wherein a plurality of measurement signal parts constitute the measurement signal.

11. The optical receiving device of claim 10, wherein the optical receiving device further comprises:

a plurality of multilevel pulse amplitude demodulators which respectively electrically connect the plurality of signal generation units to respectively receive the plurality of voltage signal parts and respectively demodulate the plurality of voltage signal parts to respectively generate a plurality of data outputs; and

an estimation module which electrically connects the control module, and electrically connects the plurality of multilevel pulse amplitude demodulators to receive the plurality of data outputs, and generates an estimating signal according to the plurality of data outputs and outputs the estimating signal to the control module, so that the control module adjusts the control signal further according to the estimating signal, the estimating signal is associated with one of a bit error rate and a signal-to-noise ratio of the optical signal.

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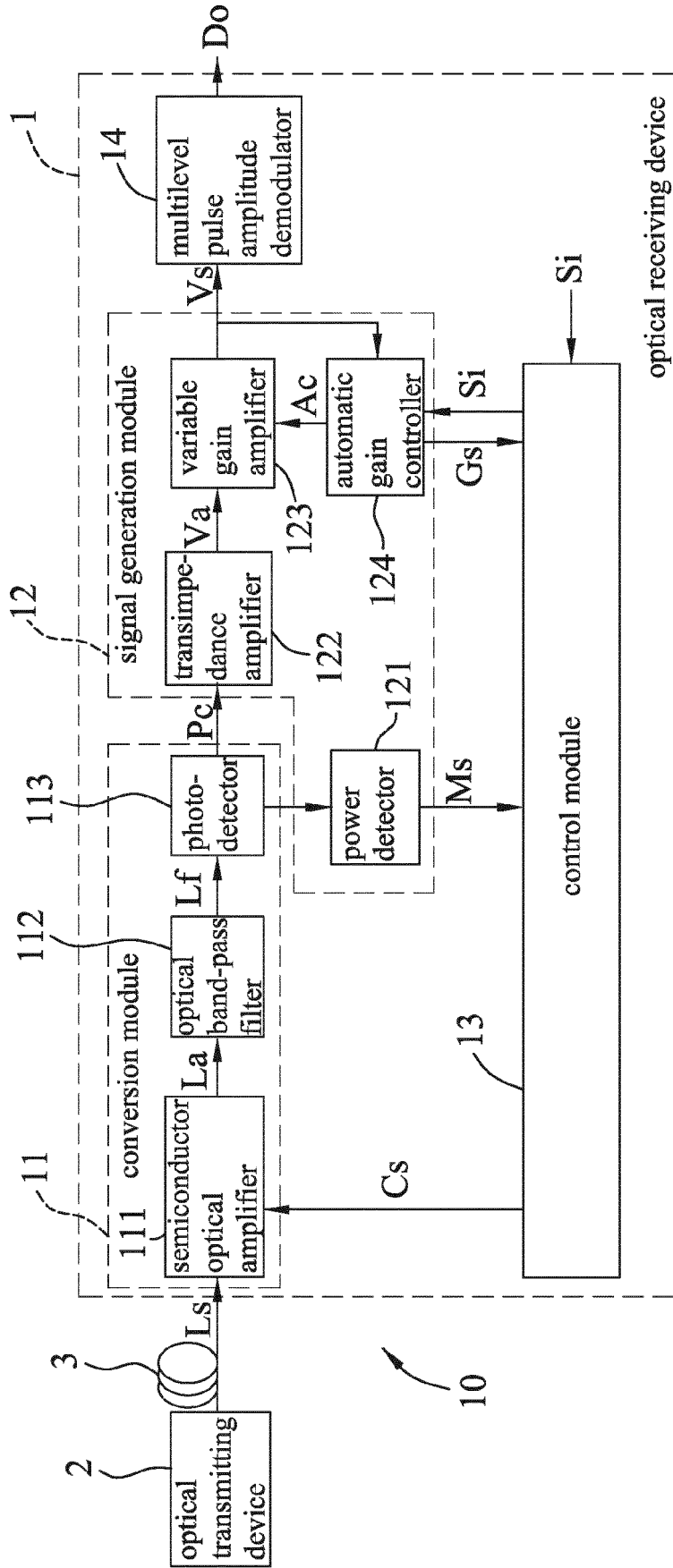


FIG.1

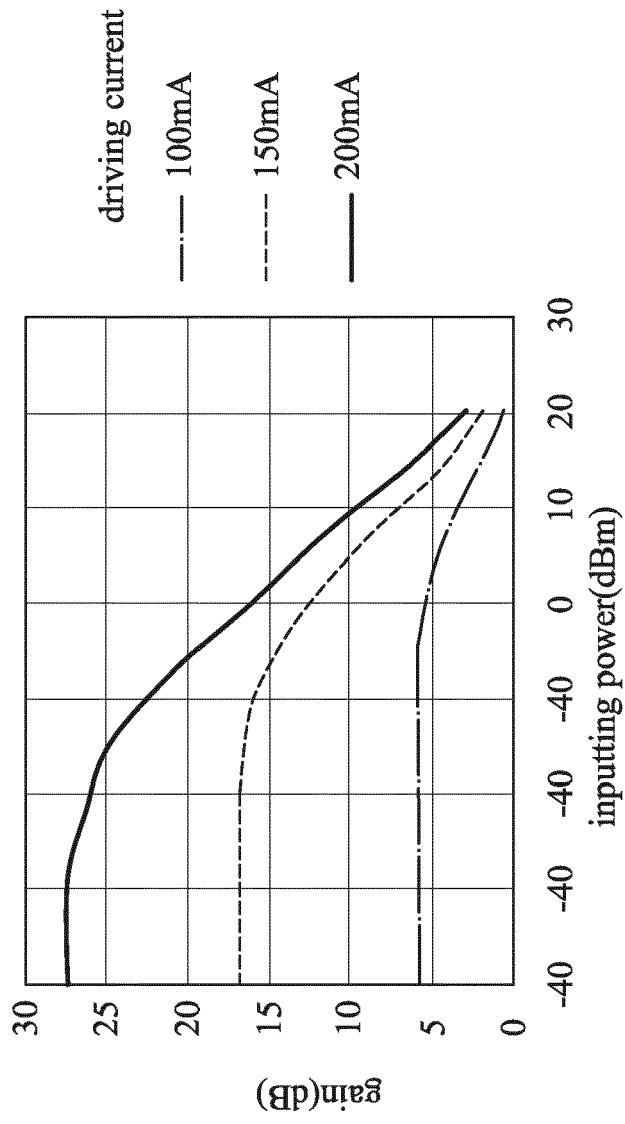


FIG.2

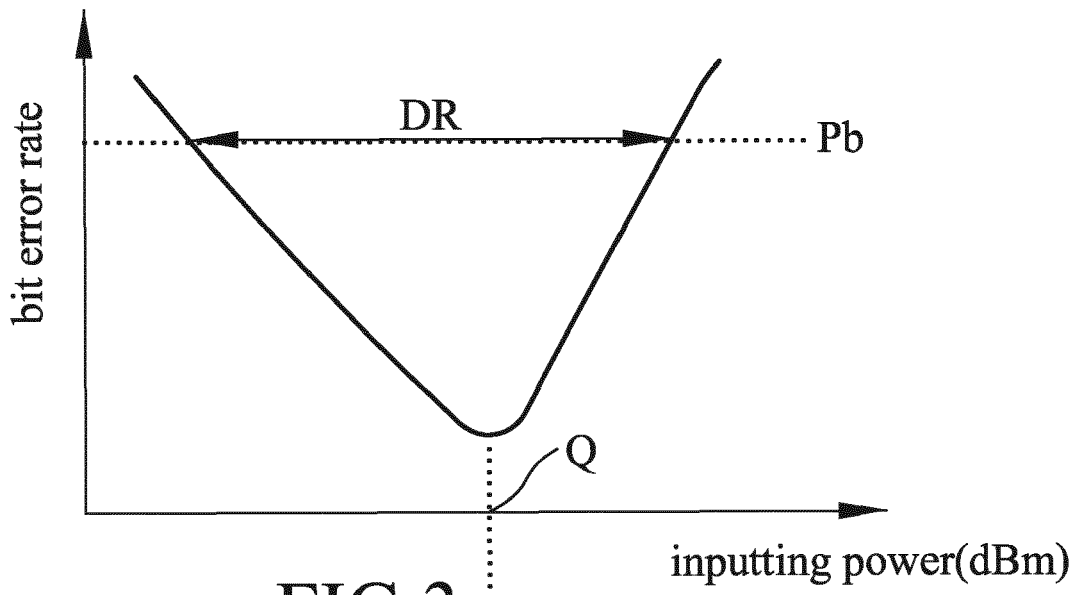


FIG.3

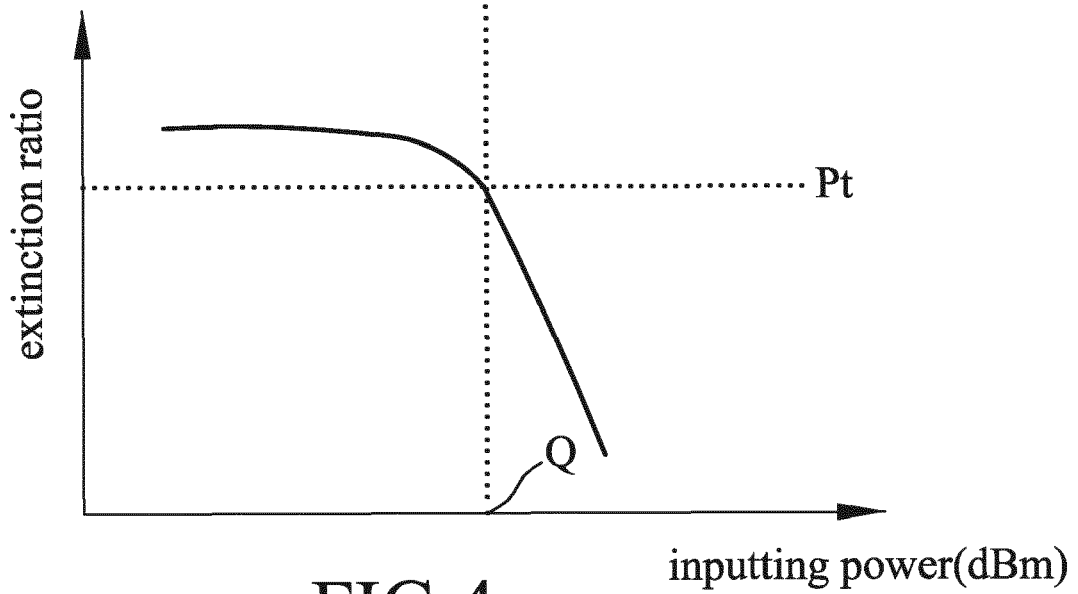
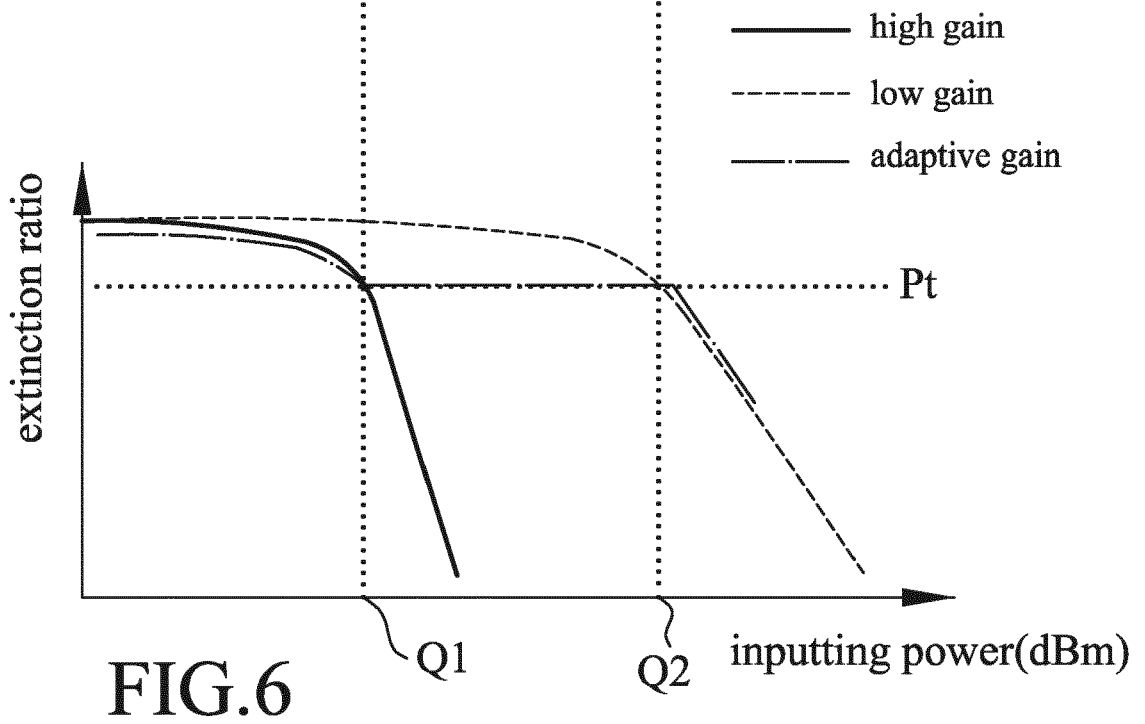
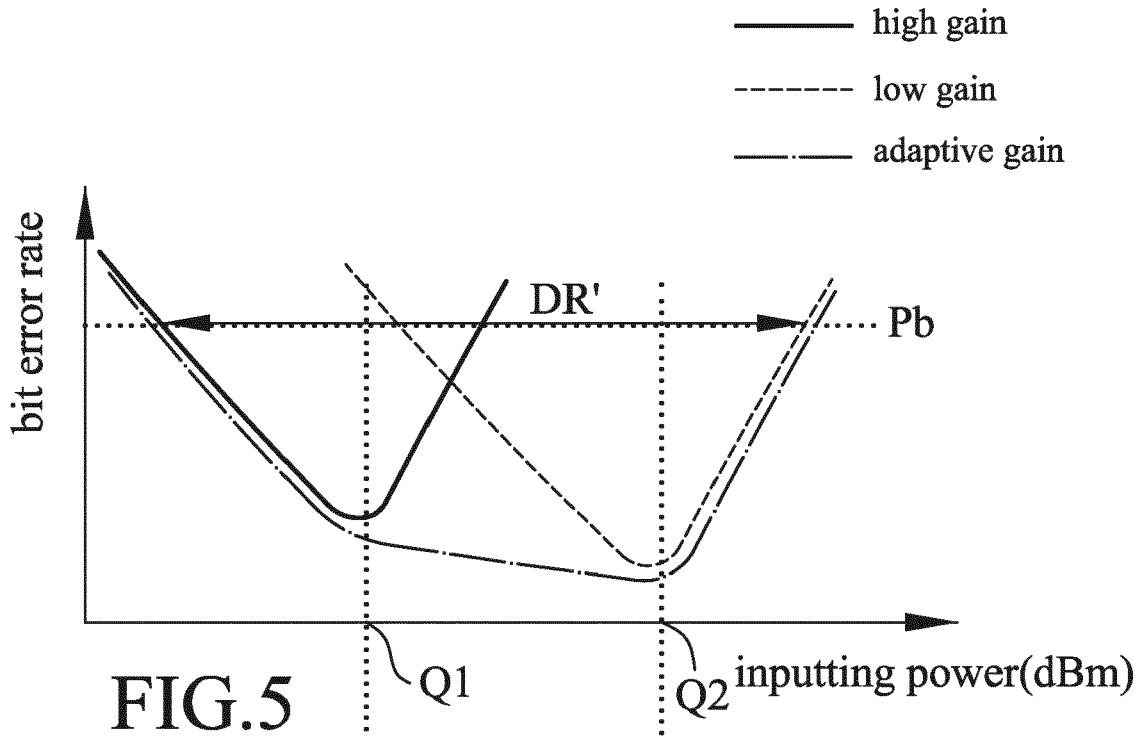


FIG.4



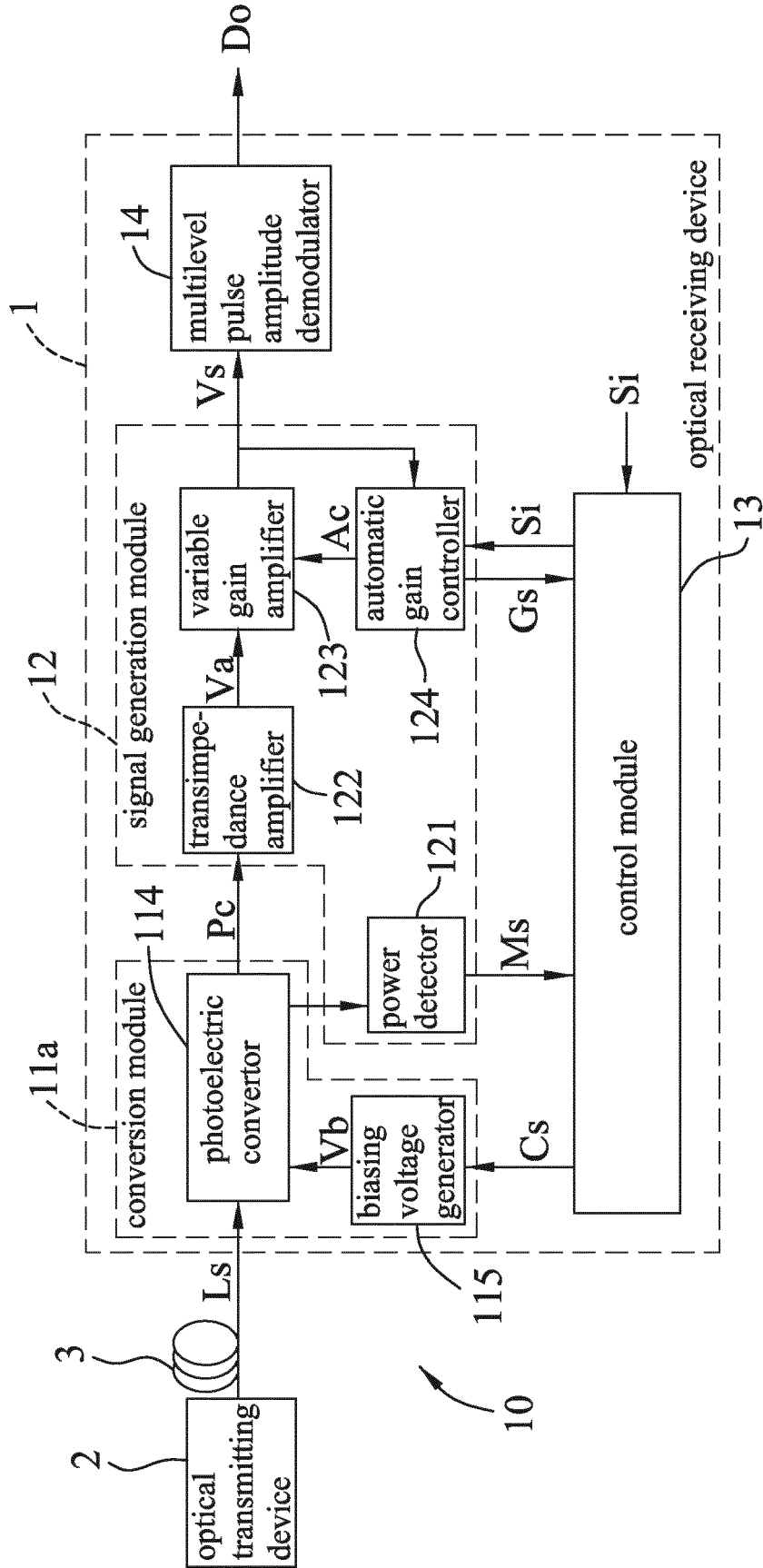


FIG.7

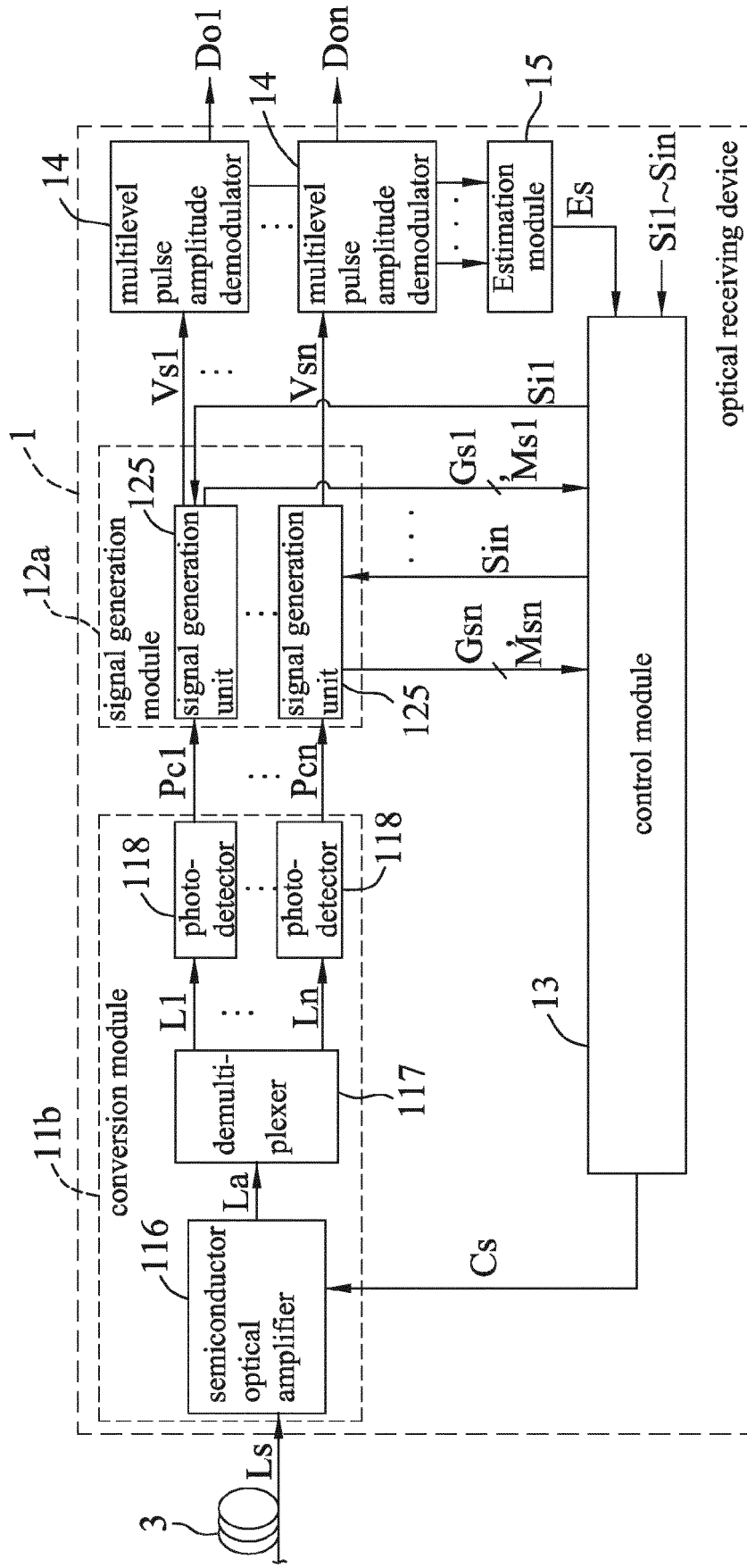


FIG.8



EUROPEAN SEARCH REPORT

Application Number
EP 21 17 5375

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A	* paragraphs [0007] - [0026]; figures 3,5 *	2-4,6,8-11	
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			H04B H03F H03G
Place of search		Date of completion of the search	Examiner
Munich		20 October 2021	Koch, Bernhard
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The members are as contained in the European Patent Office EDP file on
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20-10-2021

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